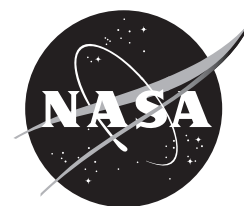


# The Earth Observer

... advancing knowledge of Earth through exploration



## In This Issue

### Meeting / Workshop Minutes

March 2005 MODIS Science Team Meeting Overview	3
Third CERES-II Science Team Meeting	8
Report on the Second International Workshop on Albedo Product Validation	13

### Other Items of Interest

NASA Helps Students "Get the Message" in Problem-Solving Competition	18
Unlocking the Mystery Behind Lightning's Puzzling Friend	20
Ozone Levels Drop When Hurricanes Are Strengthening	22

### Regular Features

EOS Scientist in the News	24
Science Calendars	27
The Earth Observer Information/ Inquiries	Back Cover

## Editor's Corner

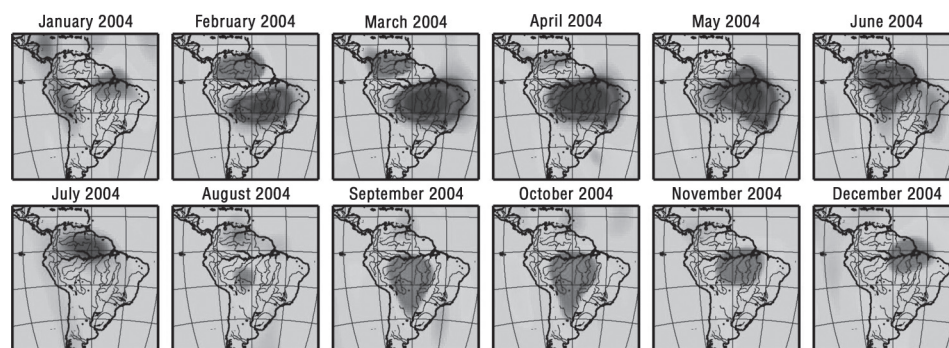
Michael King  
*EOS Project Scientist*

Responding to a recent report issued by the National Academy of Sciences, the House Appropriations Committee has held hearings and issued their own report expressing serious concern over the drastic reductions to Earth science programs that NASA has proposed. According to the Academy's report, "The aggressive pursuit of understanding Earth as a system—and the effective application of that knowledge for society's benefit—will increasingly distinguish those nations that achieve sustained prosperity from those that do not. At NASA, the vitality of Earth science and application programs has been placed at substantial risk by rapidly shrinking budgets that no longer support already-approved missions and programs of high scientific and societal relevance." To begin to address these budget shortcomings, the Committee provided \$40 M in additional funding for science at NASA above the Administration's original budget request.

I'm happy to announce that included in that amount is \$30 M in additional funding for the Glory mission. Glory is a critical mission for achieving the goals of the Climate Change Research Initiative (CCRI). This additional funding will allow for work to continue on the two instruments planned to fly on Glory—the Aerosol Polarimetry Sensor and the Total Irradiance Monitor—and also allow for work to begin on reintegration of the spacecraft bus. Work can also begin on the science data ground processing system and on education and outreach activities related to Glory. Critical design reviews for all aspects of the program—the instruments, the bus, and the ground system—will be held in 2006.

The Gravity Recovery and Climate Experiment (GRACE) continues to measure the Earth's gravity field with unprecedented accuracy and the data provided are leading to new scientific discoveries. Below is an example of how information from GRACE provides a valuable new tool that helps hydrologists study month-to-month variations in water storage over large land areas from space. The maps show the monthly fluctuation in water storage (relative to a three year average value) over South America's Amazon and Orinoco River basins during 2004. You can see the rainy and dry seasons very clearly in the Amazon basin and also see distinctly different characteristics in the smaller Orinoco basin to the north.

The Tropical Rainfall Measuring Mission (TRMM) has been given a new lease on life. Mike Griffin, NASA Administrator, announced at a public meeting on July 9 that he intends to extend the TRMM mission beyond this summer. TRMM is expected to reach the mini-



## Report on the Second International Workshop on Albedo Product Validation

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### Introduction

The 2nd International Workshop on Albedo Product Validation, sponsored by the Land Product Validation (LPV) subgroup of the Committee on Earth Observing Satellites' (CEOS) Working Group on Calibration and Validation (WGCV), was held April 27-28, 2005 as a splinter meeting within the European Geosciences Union's General Assembly in Vienna, Austria. The goal of the workshop was to discuss, initiate, and organize community validation exercises for satellite-derived land surface albedo products from CEOS members. The workshop expanded upon discussions from the first LPV albedo workshop in Boston, USA in October 2002 (Privette et al., 2002). More than 25 people from several countries and research disciplines participated.

The main components of the meeting and the related activities included discussions on:

- the albedo products being produced by CEOS members
- albedo field measurement networks
- comparison of field measurements with moderate resolution satellite albedo products (direct validation)
- inter-comparison of albedo products derived from different sensors or algorithms.

The agenda and related presentations are posted at: [lpvs.gsfc.nasa.gov/LPV\\_Albedo\\_meeting05.html](http://lpvs.gsfc.nasa.gov/LPV_Albedo_meeting05.html).

### Definitions and Products

Broadband surface albedo is generally defined as the instantaneous ratio of surface-reflected radiation flux to incident radiation flux over the shortwave spectral domain. Most current satellite albedo products are defined differently. Below we describe key characteristics that often vary among the products.

#### *Surface irradiance conventions*

To estimate albedo, most satellite algorithms rely on multiple cloud-free directional satellite observations to determine a bidirectional reflectance distribution function (BRDF) model of the surface. The model is angularly integrated to determine the reflected shortwave flux. Because most sensors do not collect multiple observations of a target in a single pass, data from multiple orbits may be used. Irradiance differences with observation time necessitate establishment of a product irradiance standard. The following albedo definitions reflect the different irradiance standards currently used in practice:

**White-sky albedo.** This corresponds to the angular integration of BRDF over both reflected and incident directions and is formally designated as the bihemispherical reflectance (BHR). It is an approximation of the albedo of the surface under diffuse (atmospherically scattered) irradiation only. The incoming radiation is often assumed isotropic, and may be designated as BHRiso. BHRiso is an intrinsic theoretical quantity that uniquely does not vary with sun angle or atmospheric state.

Alternately the apparent BHR is the bihemispherical reflectance measured under actual diffuse illumination, i.e. including the contribution of multiple reflections between the surface and the sky.

**Black-sky albedo.** This corresponds to the angular integration of BRDF over the reflected directions when illuminated only by direct (uncollided, i.e., assuming no scattering) irradiance. It is formally designated as the directional-hemispherical reflectance (DHR). It is generally computed for a specific sun position such as at the time of the satellite overpass or at local solar noon. Typically, black sky albedo increasingly exceeds white sky albedo as the solar zenith angle increases; however, this is not a firm rule and can vary with surface conditions.

**Blue-sky albedo.** This quantity is equivalent to the albedo measured in the field in that it assumes the surface is illuminated by both direct and diffuse irradiance. It depends on both the solar geometry and the atmospheric conditions, and therefore tends to change most rapidly in time. Remote sensing algorithms that estimate blue-sky albedo typically require knowledge of the surface BRDF as well as several atmospheric parameters, including aerosol amount and properties, water vapour and pressure. Alternatively, it can be approximated through the weighted combination of the black- and white-sky albedos (Lucht et al., 2000). In addition, the contribution of the possible multiple reflections between the surface and the sky can be also included.

### Temporal Compositing

Currently, no daily global albedo products from moderate resolution sensors are operationally available. The same applies to the computation of the diurnal variation of the black(blue)-sky albedo, although it is possible to simulate such temporal variations from the retrieved BRDF models and adjusted coefficients. Satellite products are either instantaneous retrievals (from multi-angular instruments) or sequential retrievals from radiometers that collect a single observation per target per orbit (where BRDFs are established from directional data collected over a short period of time). In order to maximize global coverage, products are generally provided at 8 day, 10 day, 16 day or monthly time intervals. The temporal compositing window extends from 8 days to 30 days with either a fixed or a moving centre. Such compositing poses a problem when comparing albedo over transitions periods (snow falls/melt, rapid vegetation growth/disappearance). Such cases at least need to be flagged and properly and consistently processed and documented.

### Spectral Domain

Most satellite products correspond to broad-band albedo computed over the whole shortwave radiation (SWR) spectral domain (0.3-3.0  $\mu\text{m}$ ). However, albedos for individual bands and for broad visible (VIS) (0.3-0.7 $\mu\text{m}$ ),

Photosynthetically Active Radiation (PAR) (0.4-0.7 $\mu\text{m}$ ), Near Infrared (NIR) (0.7-3.0 $\mu\text{m}$ ) bands are also available for some products.

### Ground-based Albedo Networks

Workshop presentations mainly focused on existing BSRN sites (Baseline Surface Radiation Network) including ARM (Atmospheric Radiation Measurement) and SURFRAD (Surface Radiation) sites.

BSRN (Ohmura et al., 1998) started under World Climate Research Programme (WCRP) to "Provide continuous, long-term (15 years), frequently sampled (order of seconds), state-of-the-art measurements of surface radiation fluxes adhering to the highest achievable standards of measurement procedures, calibration and accuracy." It is used to calibrate and validate satellite-based estimates of the surface radiation budget (SRB) and radiation transfer through the atmosphere. It is also used to monitor regional trends in radiation fluxes at the surface. Several facts justify the use of BSRN as a main component of the LPV direct validation planning:

1. WMO Global Atmosphere Watch (GAW) recognizes "BSRN" as the best practice in observing irradiance.
2. Global Climate Observing System (GCOS) has designated BSRN its radiation network.
3. BSRN measurement uncertainties are well defined. BSRN allows indi-

vidual scientists to determine how to meet desired uncertainties for their own stations or networks, and there is a protocol for how to establish their site's accuracy.

4. FTP file archive is available at <ftp://ezksun3.ethz.ch>.

There are currently 37 operational sites which are mainly concentrated over the U.S. and Europe, with 15 sites archiving measured (blue-sky) albedo (both incoming and reflected solar radiation). These include 8 sites with at least 10m towers such as at Boulder (USA) and Payerne (Switzerland). Additional BSRN sites measure albedo but do not necessarily archive (e.g., Lindenberg, Germany, and Bratt's Lake, Canada). The CERES ARM Validation Experiment (CAVE) provides a service to the community by hosting and reformatting a wealth of surface data, including these BSRN and ARM measurements (Rutan et al., 2001).

In addition to the BSRN sites, a large number of global flux tower sites, long-term ecological research sites, and other field sites collect albedo data. In these cases, the challenges for LPV validation will be to encourage "best practice" measurement protocols and error budgeting, as well as negotiate timely access to the data. To facilitate comparisons of field data with MODIS products, the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) has been providing 7 km x 7 km product

Sensors	Platform	Spacial Resolution <sup>1</sup>	Satellite Revisit Time <sup>2</sup>	Spectral Domain <sup>3</sup>	Temporal Restriction of Product
MODIS	Terra/Aqua	1 km	1 day	0.3-5.0	16 days
MISR	Terra	0.275-1 km	8 days	0.4-1.0	8 days
MERIS	ENVISAT	0.3-1.2 km	2-3 days	0.4-1.0	10 days
VEGETATION <sup>4</sup>	SPOT 4-5	1 km	1 day	0.4-2.4	10 days
POLDER	ADEOS 1-2	6 km	1 day	0.4-1.0	10 days
PARASOL	MYRIADE	6 km	1 day	0.4-1.0	10 days
SEVIRI	MSG	1-3 km	15 min	0.4-1.6	1-10 days
Meteosat	GOES	2.25 km	30 min	0.4-0.8	10 days
ISCCP	(climatology)	60 km	N/A	0.3-3.0	30 days
ECOCCLIMAP	(climatology)	1km	N/A	0.3-3.0	30 days

**Table 1.** Sensors and products considered within the workshop. <sup>1</sup> spacial resolution at the equator; <sup>2</sup> revisit of the sensor at the equator; <sup>3</sup> wavelength ( $\mu\text{m}$ ) of the shorter and longer spectral band used; <sup>4</sup> a Wide Field-of-View Sensor on the SPOT-4 satellite.

subsets over both BSRN sites and a large set of other tower sites.

Research challenges discussed in the field validation of albedo included adjusting for the spatial heterogeneity of some sites and possible albedo variability within compositing periods, and the up-scaling procedures required to allow comparison of point tower measurements with medium resolution satellite products.

### Requirements for Albedo Products and Their Validation

Although relatively few albedo “end users” were represented during the workshop, the participants suggested the main user requirements as:

- Availability of long and consistent time series of albedo values over the globe. This point forces the need to address the necessary temporal consistency within sensors as well as between the several sensors used from the beginning (e.g., AVHRR in 1982). For this reason, inter-comparison between products is mandatory.
- Data gaps (spatial or temporal) pose a problem to some users. Methods of ‘gap filling’ should be also included as an important issue in the development of albedo products.

- The accuracy/uncertainties values should be associated to the albedo products. The validation activity could be extended to the evaluation of these vital quality assessment criterions.

### Albedo Product Inter-comparison

Workshop participants agreed that the different satellite products should be systematically compared in an LPV community activity (hereafter called inter-comparison). The inter-comparison must encompass a range of areas (land cover and atmospheric characteristics). The presentations of inter-comparisons accomplished thus far were followed by discussions leading to a proposal for the organisation of this inter-comparison activity.

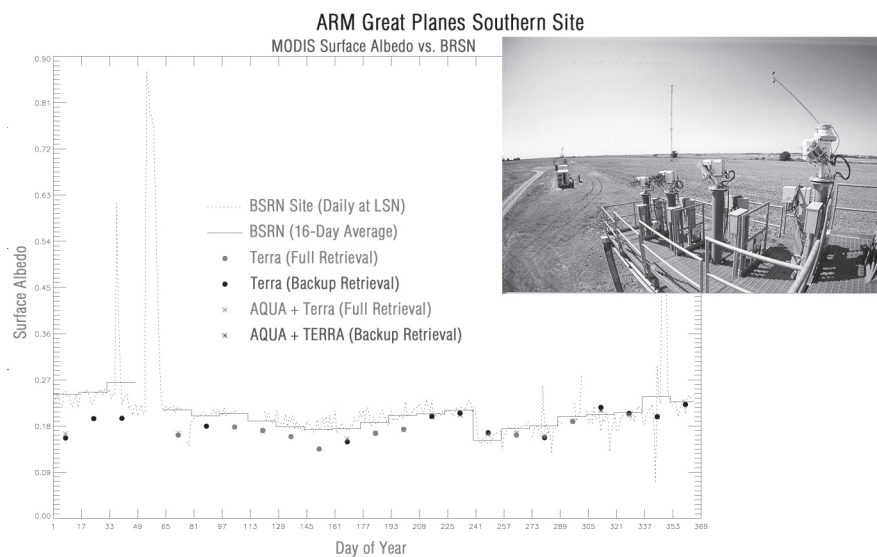
The inter-comparison of products has to be organized to be efficient. Similar to what was proposed for the LAI/fAPAR (Leaf Area Index/fraction of Absorbed PAR) validation exercise (Morissette et al., 2005), albedo products could be inter-compared over a consensus network of sites and periods. Each team in charge of a product should extract the albedo products over the selected sites and periods, and make them available to the community by posting a link through

the LPV web site. Several more detailed aspects of this exercise were discussed, leading to the following proposition:

**Product type.** focus on current operational products as listed in Table 1. Priority was set on the white-sky albedo products (BHRiso) that are computed for all the products. However black-sky (and blue-sky when available) albedo products are also of interest although the definition may slightly vary from product to product. Comparison will be conducted for VIS (0.3-0.7), NIR (0.7-3.0 $\mu$ m) and SWR (0.3-3.0 $\mu$ m).

**Spatial and temporal resolution.** Studies should be conducted over a range of spatial resolutions currently used in practice, including 1/2°, 1/4° and 1/15°. The inter-comparison could not be achieved at a higher spatial resolution than 1/30° without accounting for possible perturbations by geometrical problems such as co-registration accuracy and point-spread-function effects. The temporal resolution will mainly depend on the products. Although daily to monthly products will be inter-compared, attention should be also paid to the diurnal variation (BRDFs) as simulated from the various sensors and algorithms.

**Spatial and temporal domain.** Researchers will focus on data from Year 2003 since most of the sensors from which albedo products are derived were flying (e.g., MODIS, MERIS, VEGETATION, POLDER, MISR, MSG, Meteosat). The spatial domain will be global within  $\pm 70^\circ$  latitude, with special emphasis on the Meteosat/MSG field of view (i.e. Europe and Africa). This will be achieved by sampling the surface according to the proposed BELMANIP (Baret et al., 2006) network of sites designed to represent the prevalent surface types and conditions. In North America, emphasis will be placed on the mid-continent and will utilize the ARM sites, the BSRN sites and any appropriate flux tower locations. The list of sites considered, with 1/2° extent and without overlap will be posted at the LPV site.



**Figure 1:** An example of combined field and satellite data. The continuous lines on the graph represent field measurements albedo values while the dots represent albedo estimates from MODIS. The proposed virtual experiment will build on this type of analysis.

Within this exercise, particular attention should be paid to the transition situations where a rapid and significant change of albedo values are expected, mainly corresponding to snow fall/melting and greening-up/senescence or harvesting of the vegetation.

### Direct Comparison of Products with Field Measurements

The comparison of field measurements with satellite-derived products is hereafter called 'direct validation.' Both the exploitation of data from past field campaigns, dubbed 'virtual experiments,' and the organization of new field campaigns for 2006 were discussed.

#### Virtual experiments

To expedite a community-wide evaluation of products, participants agreed to initially exploit data from past field experiments (particularly 2003). Candidate sites include:

- ARM SGP (Southern Great Plains; semiarid grasslands and crops) and NSA (Northern Study Area in Barrow, Alaska; tundra), and BOREAS (boreal forest) sites; Point of Contact (POC): A. Trishchenko
- Bratts-Lake, Canada (northern grasslands); POC: B. McArthur
- Mongu, Zambia (Kalahari woodlands); POC: J. Privette
- Barrax site, Spain (agricultural site with large fields); POC: J. L. Roujean, F. Baret
- Amazonian site, Brazil (tropical forest): POC, R. Pinker

MISR, CHRIS/PROBA, and ASTER images could be used to more rigorously investigate scaling-up problems that occur over heterogeneous areas. Additional high spatial resolution images, such as Landsat, SPOT, and IKONOS, could be used in complement to document the spatial heterogeneity. Several up-scaling methods could be compared over these sites. In addition, it was proposed to use radiative transfer model simulations of landscapes as presented by S. Dutoit,

to better evaluate the uncertainties associated with the scaling up techniques in heterogeneous conditions. Figure 1 shows some initial results from the ARM SGP site, comparing field measurements with MODIS-derived albedo estimates.

#### New experiments

Because many research problems (especially scaling) cannot be adequately resolved with past field data sets, the participants developed general plans to conduct a community field campaign focused on albedo. Suggested conditions for a new field experiment were the following:

- Based on existing and on-going field campaigns to reduce costs.
- Preferentially located over an area where rapid and significant albedo changes are expected.
- Preferentially located within the MSG/Meteosat field of view or over the North American mid-continent.
- Have the possibility to replicate albedo measurements at several places within the site to document the spatial variability.

Three possible sites were proposed for 2006. One site in Africa is within the Analyses Multidisciplinaires de la Mousson Africaine (AMMA) project area, where there is already a significant experimental effort deployed on ground. Year 2006 will coincide with the peak in experimental activities in the AMMA project. The airborne POLDER camera, which provides a very unique way to measure albedo from limited altitude, will be flown. This albedo validation campaign would potentially allow comparison of ground measurements acquired by several teams, as well as replicate sampling in several places. J.L. Roujean and F. Baret are leading the definition and initialisation of this campaign in collaboration with the AMMA. In North America, it may be possible to leverage some efforts associated with the North American Carbon Project (NACP) to conduct a mid-continent albedo field campaign in 2006. Finally,

there are possible opportunities for an experiment within Russia, although the Siberia II effort is coming to an end. Participants agreed that the relative merits of these sites must be further investigated, and that one or possibly two 2006 field campaigns are a reasonable goal.

### Conclusion

This second albedo validation meeting was successful in terms of participants, information gathered on current validation exercises, and development of plans for the future. It appears that current albedo products, despite the different sensors, algorithms and definitions, agree relatively well with each other and with ground measurements. This may result from the spectral and directional integrations required for albedo computation, since this is a process that tends to reduce some noise associated to the top of canopy reflectances as measured from the satellites, and thus yields relatively robust results. However, several issues must still be resolved to achieve the very demanding accuracy required by many users (better than 2% to 5% relative accuracy; e.g., Henderson-Sellers A. and M.F. Wilson, 1983). The challenges include problems associated with BRDF determination from limited directional sampling imposed by sun-view geometry and cloud occurrence, residual (or subpixel) clouds after cloud screening, residual atmospheric correction effects, temporal compositing, and narrow to broad-band spectral conversion.

Validation activities should focus both on inter-comparison of products achieved over an extensive and representative set of sites such as was defined during this meeting. Direct validation must also be developed, with due attention to the scaling-up problems over heterogeneous landscapes, and possibly focusing over rapid transition areas and periods where possible problems and differences between products may be more common. Exploitation of past field efforts (e.g., from 2003) as well as the execution of campaigns in 2006 was proposed to

complement the activities that were presented during this workshop. This will be the subject of discussion at the next meeting, possibly occurring in late 2005 or early 2006.

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## Glossary

### Satellite Instruments

**ASTER** – Advanced Spaceborne Thermal Emission and Reflection Radiometer

**AVHRR** – Advanced Very High-Resolution Radiometer

**MODIS** – Moderate-Resolution Imaging Spectroradiometer

**MISR** – Multi-angle Imaging Spectroradiometer

**MERIS** – Medium-Resolution Imaging Spectrometer

**VEGETATION** – a Wide Field-of-View Sensor on the SPOT-4 satellite

**POLDER** – Polarization and Directionality of the Earth's Reflectance

**SEVIRI** – Spinning Enhanced Visible And Infra-Red Imager (instrument for MSG)

**CHRIS/PROBA** – CHRIS (Compact High Resolution Imaging Spectrometer) imaging spectrometer onboard space platform PROBA (Project for On Board Autonomy)

### Satellite Platforms

**Aqua** – NASA Earth Observing System, sunsynchronous afternoon satellite

**Terra** – NASA Earth Observing System, sunsynchronous morning satellite

**ENVISAT** – Environmental Satellite, European Space Agency

**SPOT 4-5** – Systeme pour l'Observation de la Terre (France)

**ADEOS 1-2** – Advanced Earth Observation Satellite

**MYRIADE** – CNES (France) satellite series

**PARASOL** – Polarization & Anisot-

ropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (satellite in Myriade series)

**GOES** – Geostationary Operational Environmental Satellite (U.S.)

**IKONOS** – Space Imaging's earth imaging satellite

**Landsat** – Land Remote-Sensing Satellite (U.S.)

**Meteosat** – Geostationary Satellite (Europe)

**MSG** – Meteosat Second Generation

### Data Projects

**ISCCP** – International Satellite Cloud Climatology Project

**ECOCCLIMAP** – Global Database Of Land Surface Parameters At 1km Resolution In Meteorological And Climate Models



(continued from p.7)

in models is increasing also and in many, if not all cases is resulting in improved scientific results. A good start on data fusion of MODIS observations with other instruments is occurring, but much more can profitably be done in the future. This is true not only for instruments on the Terra and Aqua missions, but with other instruments on other spacecraft. In general, the mid to long-term future looks good with the Terra and Aqua MODIS instruments working well and the MODIS-derived VIIRS instrument projected for operation on the NPP mission and the NPOESS series.

Emphasis at the next meeting will be even more on science and applications with continued emphasis on the use and assimilation of MODIS observations in models along with data fusion. Posters along with plenary and discipline group presentations will be encouraged. This meeting will be between six months and one year from now—probably toward end of the calendar year.





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